**International Journal of Advanced Research in Engineering and Technology (IJARET)**
Volume 12, Issue 11, November 2021, pp. 63-74, Article ID: IJARET_12_11_007
Available online at https://iaeme.com/Home/issue/IJARET?Volume=12&Issue=11
ISSN Print: 0976-6480 and ISSN Online: 0976-6499
DOI: https://doi.org/10.34218/IJARET.12.11.2021.007



# ANALYSIS OF EMISSION FACTOR IN THAILAND FOR VEHICLE TRANSPORTATION THAT AFFECTS THE CARBON FOOTPRINT IN THE PRODUCTION PROCESS OF THAI DENDROCALAMUS GIGANTEUS BAMBOO (TDG) LAMINATED

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**ABSTRACT**

*Carbon Footprint value in the production of laminated Thai Dendrocalamus Giganteus bamboo (TDG) [1] [2] [3] [4] [5][6][7]. Data collection comes from actual transport in the research production process and Thai National LCI Database/MTEC (With TGO Electricity 2014). Therefore, the study of the Emission Factor of each type of transport that exists in Thailand is important to reduce the Carbon Footprint. Although in the research process, most of the transportation is caused by transporting raw material from plantation to the lab. The analysis of the results in this research was found that the weight of the load per trip had an effect on Maximum Emission. The 0% one way transport results in high emissions, which also results in a higher carbon footprint.*

**Key words:** Emission value, Factor, ANOVA, Tukey's HSD, Dendrocalamus Giganteus.

**Cite this Article:** Rachata Prokarug, Waranon Kongsong and Chaleeporn Thammapornram, Analysis of Emission Factor in Thailand for Vehicle Transportation that Affects the Carbon Footprint in the Production Process of Thai Dendrocalamus Giganteus Bamboo (TDG) Laminated, *International Journal of Advanced Research in Engineering and Technology (IJARET).* 12(11), 2021, pp. 63-74.
https://iaeme.com/Home/issue/IJARET?Volume=12&Issue=11

# 1. INTRODUCTION

Climate change has been identified as one of the major challenges facing the world today, and there are concerted efforts at a global level to reduce the emissions of greenhouse gases (GHGs) which contribute to global warming. It has increasingly been recognized that emissions of GHGs are not only related directly to energy conversion (which no doubt is a major contributor), but also indirectly through the consumption of goods and services. In this regard it has become widely acknowledged that sustainable consumption and production are imperative to maintain sustainable economies in the face of population growth as well as increasing living standards. [11]

Transportation is a major contributor to global climate change representing approximately 20% of the world total CO2 emissions from fossil fuel combustion in 2013 [9] Quantification of emissions related to the product transportation often present several difficulties, most of them related to factor as the emission sources selected for the study, the fuel consumption quantification and the fuel emission factor among others [10] canceling the avoided emissions form carbon savings.

Environmental impact of freight transport operations represents a worldwide concern. To establish the emissions related to transport activities usually there are three type of data that is representative to make the estimation of the amount of GHG released to the environment: a) amount of fuel consumed during transportation, b) economic value related to the fuel consumption, and c) traveled distance, type and model of the transport vehicle [12] However, supply chain structure and vehicle utilization strongly influence the environmental performance of freight transport sector and CO2 emissions are clearly becoming significant factors in logistical decision-making. This can be seen on such way that over 50% of companies involved in road freight transport operations are likely to see their activities affected by climate change effects in the years to come [12]. Thereby, decision making on product development should consider application of regional natural fibers on the design of bio composite materials, reducing costs and relieving.

Factors affecting greenhouse gas emissions from transportation of goods, greenhouse gas emission, and energy consumption in the transport sector depend on the influence of four factors.

*Activity :* A refer to the amount of goods transported generally expressed in (Vehicle – Kilometer, vkm) or (Ton –Kilometer, tkm)

*Mode share :* S refer to the type of vehicle in which the vehicle each type had a different amount of energy demand.

*Fuel intensity:* I refer to amount of energy used per unit of activity. Transportation is generally expressed in units liter per kilometer for vehicle travel or liters per ton – kilometer

*Fuel Choice:* F means choosing the type of fuel used for transportation because each type of fuel has different energy efficiency including quantity and ability to control emission and greenhouse gases

Recent research studies have found that the carbon footprint arising from the transportation process has the highest value in the laminated bamboo production process in the research of [1][2][3][4][5][6][7]. Thai Dendrocalamus Gigantues Bamboo (TDG) from Nan province Giant bamboo has been used in research of [8][15] due to the test results of physical, chemical and mechanical properties that are suitable for use in processed bamboo in construction. Relationship study of factors affecting emission values It is considered very important in the production process. The transport process has the highest carbon footprint, meaning it has a high emission. Therefore, this study is an analysis of transportation processes in Thailand as a guideline to develop and reduce the carbon footprint in the future.

## 2. RESEARCH OBJECTIVES

The purpose of this research was to study the factors affecting the emission value in the transportation process by classified into 4 parts:

- Type of vehicle
- Load of vehicle
- Percent of load
- Travel Type

## 3. MATERIALS AND METHODS

In this study data analysis based on data from Thai National LCI Database/MTEC (With TGO Electricity 2014) The survey that set for this study set into 4 parts for this research the focus factor; Car Load, Travel Type and percent load as the following

**Vehicle Load** for this research were the weight of the car for this study 1.5, 7, 8.5, 11, 16, and 32 tons as following the table

**Table 1** Key set the Vehicle load

| | **Ton** | **score** |
|---|---|---|
| Vehicle Load | 1.5 | 1 |
| | 7 | 2 |
| | 8.5 | 3 |
| | 11 | 4 |
| | 16 | 5 |
| | 32 | 6 |

**Travel Type** for this research each traveling set into Normal and Rough as shown in table 2

**Table 2** Key set for travel type

| | | |
|---|---|---|
| Travel type | Normal | 1 |
| | Rough | 2 |

**The percent load for** this paper devised into 0, 50, and 75,100 percent load each traveling time. As shown in the table 3

**Table 3** Key set for travel type

| | | |
|---|---|---|
| % load | 0 | 1 |
| | 50 | 2 |
| | 75 | 3 |
| | 100 | 4 |

**The Vehicle type** for this paper divided into 4,5,6,10,18,20 and 22 wheel the key set for analysis

**Table 3** Key set for travel type

| | | |
|---|---|---|
| No.wheel drive | 4 Wheel | 1 |
| | 5 Wheel | 2 |
| | 6 Wheel | 3 |
| | 10 Wheel | 4 |
| | 18 Wheel | 5 |
| | 20Wheel | 6 |
| | 22 Wheel | 7 |

# 4. TESTING AND TESTING STANDARD

## 4.1. Data Analysis

Based on data from Thai National LCI Database/MTEC (With TGO Electricity 2014) by comparing Descriptive, Predictive, Prescriptive, and Diagnostic Analytics

Descriptive analytics looks at data statistically to tell you what happened in the past. Descriptive analytics to understand how it is performing by providing context to help research interpret information. This can be in the form of data visualizations like graphs, charts, reports, and dashboards. Diagnostic analytics takes descriptive data a step further and provides deeper analysis to answer the question: Why did this happen? Often, diagnostic analysis is referred to as root cause analysis. This includes using processes such as data discovery, data mining, and drill down and drill through. Predictive analytics takes historical data and feeds it into a machine learning model that considers key trends and patterns. The model is then applied to current data to predict what will happen next. Prescriptive analytics takes predictive data to the next level. Now that we have an idea of what will likely happen in the future, what should we do? It suggests various courses of action and outlines what the potential implications would be for each.

## 4.2. Statistical Test with HSD

Tukey's HSD (honestly significant difference) test, [13] is a single-step multiple comparison procedure and statistical test. It can be used to find means that are significantly different from each other. Named after John Tukey, [14]it compares all possible pairs of means, and is based on a studentized range distribution ($q$) (this distribution is similar to the distribution of $t$ from the *t-test*.[15] Tukey's test compares the means of every treatment to the means of every other treatment; that is, it applies simultaneously to the set of all pairwise comparisons

$$\mu_i - \mu_j$$

And identifies any difference between two means that is greater than the expected standard error. The confidence coefficient for the set, when all sample sizes are equal, is exactly 1-α for any $0 \leq \alpha \leq 1$. For unequal sample sizes, the confidence coefficient is greater than $1 - \alpha$. In other words, the Tukey method is conservative when there are unequal sample sizes.

**The Test Statistic** Tukey's test is based on a formula very similar to that of the *t*-test. In fact, Tukey's test is essentially a *t*-test, except that it corrects for family-wise error rate.

The formula for Tukey's test is:

$$q_s = \frac{Y_A - Y_B}{SE}$$

where $Y_A$ is the larger of the two means being compared, $Y_B$ is the smaller of the two means being compared, and SE is the standard error of the sum of the means. This $q_s$ value can then be compared to a $q$ value from the studentized range distribution. If the $q_s$ value is *larger* than the critical value $q_\alpha$ obtained from the distribution, the two means are said to be significantly different at level

$$\alpha:0 \leq \alpha \leq 1$$

Since the null hypothesis for Tukey's test states that all means being compared are from the same population (i.e. $\mu_1 = \mu_2 = \mu_3 = ... = \mu_k$), the means should be normally distributed (according to the central limit theorem). This gives rise to the normality assumption of Tukey's test.

## 5. RESULTS AND DISCUSSION

Data analysis based on data from Thai National LCI Database/MTEC (With TGO Electricity 2014) as shown in table 1

**Table 1** Analysis the Emission Value

| No. | Load | Load 0% | | Load 50% | | Load 75% | | Load 100% | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | R | N | R | N | R | N | R |
| 1 | 1.5 | 0.2416 | 0.3092 | 0.3807 | 0.4697 | 0.2707 | 0.3077 | 0.2155 | 0.2557 |
| 2 | 7 | 0.3347 | 0.4108 | 0.3403 | 0.3673 | 0.2406 | 0.2552 | 0.1836 | 0.1992 |
| 3 | 7 | 0.3133 | 0.3752 | 0.2699 | 0.3166 | 0.1841 | 0.2140 | 0.1411 | 0.1627 |
| 4 | 8.5 | 0.4071 | 0.4230 | 0.1198 | 0.1302 | 0.0843 | 0.0913 | 0.0653 | 0.0691 |
| 5 | 8.5 | 0.4276 | 0.5136 | 0.1248 | 0.1444 | 0.0875 | 0.0991 | 0.0678 | 0.0750 |
| 6 | 8.5 | 0.4376 | 0.5601 | 0.1021 | 0.1229 | 0.0716 | 0.0864 | 0.0547 | 0.0679 |
| 7 | 11 | 0.4926 | 0.6086 | 0.1083 | 0.1346 | 0.0768 | 0.0943 | 0.0614 | 0.0734 |
| 8 | 16 | 0.5751 | 0.6783 | 0.0853 | 0.1044 | 0.0590 | 0.0725 | 0.0454 | 0.0553 |
| 9 | 16 | 0.6056 | 0.6678 | 0.0881 | 0.1019 | 0.0617 | 0.0739 | 0.0489 | 0.0612 |
| 10 | 16 | 0.5903 | 0.7517 | 0.0972 | 0.1202 | 0.0691 | 0.0841 | 0.0533 | 0.0639 |
| 11 | 32 | 0.8219 | 0.9968 | 0.0804 | 0.0914 | 0.0577 | 0.0655 | 0.0449 | 0.0523 |
| 12 | 32 | 0.7875 | 0.8662 | 0.0730 | 0.0858 | 0.0518 | 0.0628 | 0.0404 | 0.0502 |
| 13 | 32 | 0.8688 | 1.0663 | 0.0803 | 0.0979 | 0.0569 | 0.0687 | 0.0444 | 0.0533 |
| 14 | 32 | 1.0026 | 0.8408 | 0.0921 | 0.0840 | 0.0651 | 0.0595 | 0.0508 | 0.0448 |
| 15 | 32 | 0.8408 | 1.1447 | 0.0840 | 0.1011 | 0.0595 | 0.0706 | 0.0448 | 0.0547 |
| 16 | 32 | 1.0212 | 1.2459 | 0.0866 | 0.1042 | 0.0597 | 0.0711 | 0.0459 | 0.0540 |

## 5.1. Vehicle Weight

Increased vehicle weight affects the Carbon Footprint value in the transportation process The test results are shown in Fig. 1, the percentage of load is 0. The weight of the vehicle affects the emission value.

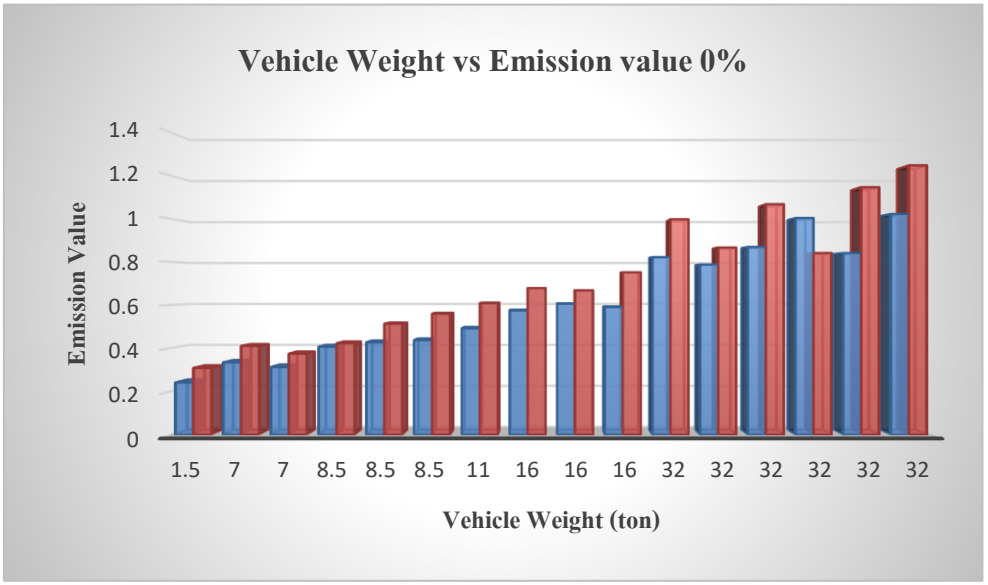


**Figure 1** Vehicle Weight vs Emission value with 0% load

With the percent load of the car 50%, 75%, 100%The weight of the cargo affects the emission value. Lighter vehicles that can be loaded have a higher emission value than vehicles with higher loads. The test results are shown in figure 2,3,4 from the blue bar graph. shows the normal travel style compared to the tough trip on the red bar chart. It can be seen that the rugged journey has a higher mission value.

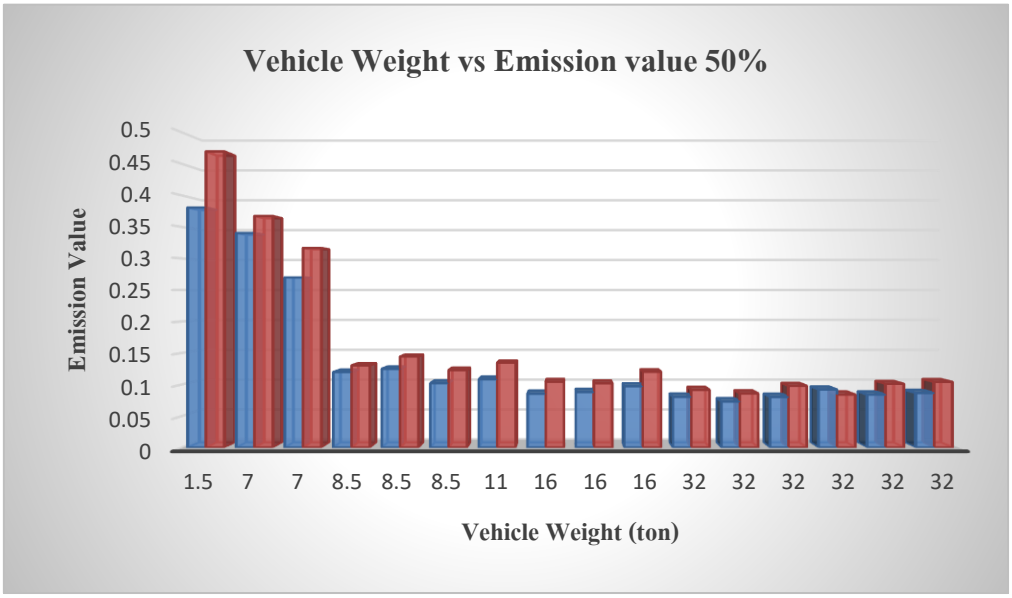


**Figure 2** Vehicle Weight vs Emission value with 50% load

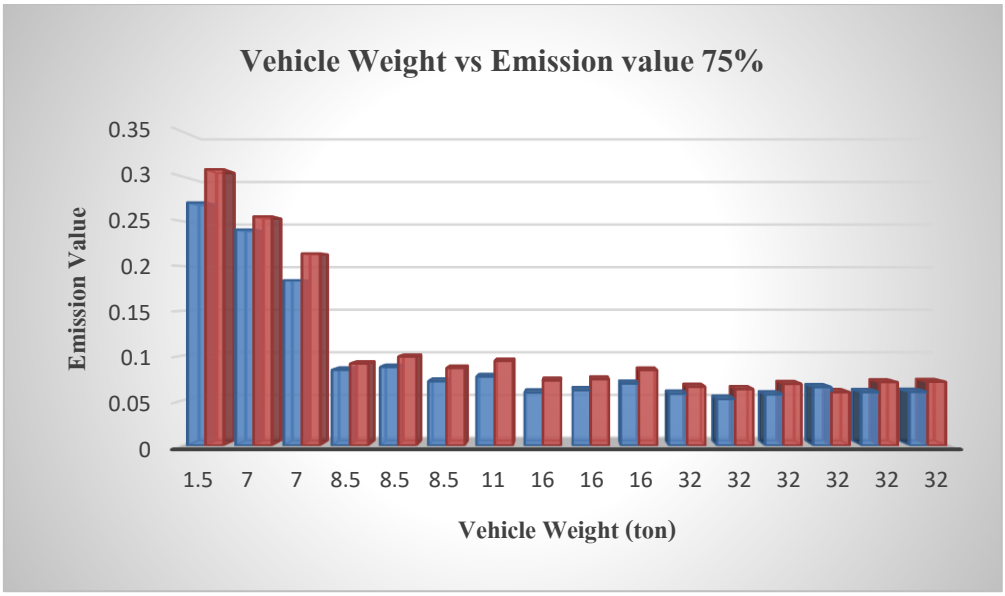


**Figure 3** Vehicle Weight vs Emission value with 75 % load

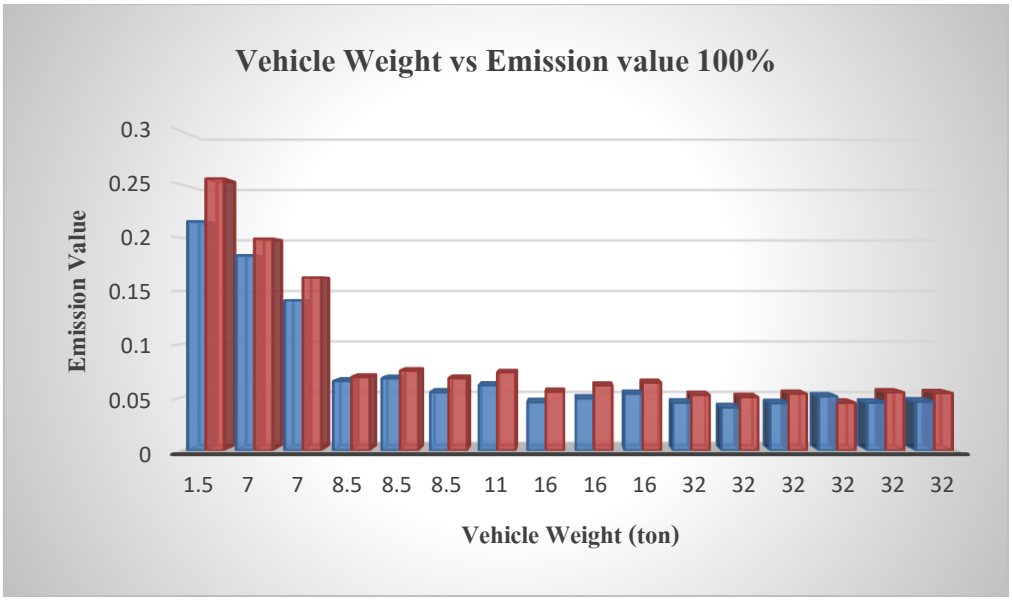


**Figure 4** Vehicle Weight vs Emission value with 100% load

## 5.2. Vehicle Type

Analyze the type of car to compare Emission values for this research, The following sample groups are based on the number of wheels such as 4,6,10,18,20,22 wheels and down to specific characteristics such as pickup trucks, vans, divided into small and large sizes. The Analysis the emission Value as shown in the table 2 a 20-wheel vehicle with rough driving, 0 percent load, has the highest emission value of 1.2456, which has a higher emission effect on the carbon footprint.

**Table 2** Analysis the Emission Value

| No. | Type Car | Load 0% | | Load 50% | | Load 75% | | Load 100% | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | R | N | R | N | R | N | R |
| 1 | 4 | 0.2416 | 0.3092 | 0.3807 | 0.4697 | 0.2707 | 0.3077 | 0.2155 | 0.2557 |
| 2 | 4 | 0.3347 | 0.4108 | 0.3403 | 0.3673 | 0.2406 | 0.2552 | 0.1836 | 0.1992 |
| 3 | 4 | 0.3133 | 0.3752 | 0.2699 | 0.3166 | 0.1841 | 0.2140 | 0.1411 | 0.1627 |
| 4 | 6 | 0.4071 | 0.4230 | 0.1198 | 0.1302 | 0.0843 | 0.0913 | 0.0653 | 0.0691 |
| 5 | 6 | 0.4276 | 0.5136 | 0.1248 | 0.1444 | 0.0875 | 0.0991 | 0.0678 | 0.0750 |
| 6 | 6 | 0.4376 | 0.5601 | 0.1021 | 0.1229 | 0.0716 | 0.0864 | 0.0547 | 0.0679 |
| 7 | 6 | 0.4926 | 0.6086 | 0.1083 | 0.1346 | 0.0768 | 0.0943 | 0.0614 | 0.0734 |
| 8 | 10 | 0.5751 | 0.6783 | 0.0853 | 0.1044 | 0.0590 | 0.0725 | 0.0454 | 0.0553 |
| 9 | 10 | 0.6056 | 0.6678 | 0.0881 | 0.1019 | 0.0617 | 0.0739 | 0.0489 | 0.0612 |
| 10 | 10 | 0.5903 | 0.7517 | 0.0972 | 0.1202 | 0.0691 | 0.0841 | 0.0533 | 0.0639 |
| 11 | 18 | 0.8219 | 0.9968 | 0.0804 | 0.0914 | 0.0577 | 0.0655 | 0.0449 | 0.0523 |
| 12 | 18 | 0.7875 | 0.8662 | 0.0730 | 0.0858 | 0.0518 | 0.0628 | 0.0404 | 0.0502 |
| 13 | 18 | 0.8688 | 1.0663 | 0.0803 | 0.0979 | 0.0569 | 0.0687 | 0.0444 | 0.0533 |
| 14 | 18 | 1.0026 | 0.8408 | 0.0921 | 0.0840 | 0.0651 | 0.0595 | 0.0508 | 0.0448 |
| 15 | 20 | 0.8408 | 1.1447 | 0.0840 | 0.1011 | 0.0595 | 0.0706 | 0.0448 | 0.0547 |
| 16 | 20 | 1.0212 | 1.2459 | 0.0866 | 0.1042 | 0.0597 | 0.0711 | 0.0459 | 0.0540 |

From the comparison chart as shown in Fig. 5, it is shown that the 20-wheel vehicle type, aggressive driving from the orange bar graph, had the highest emission value at 0 percent loading. Most wheels is corresponds to a car with a lot of wheels will weigh more.

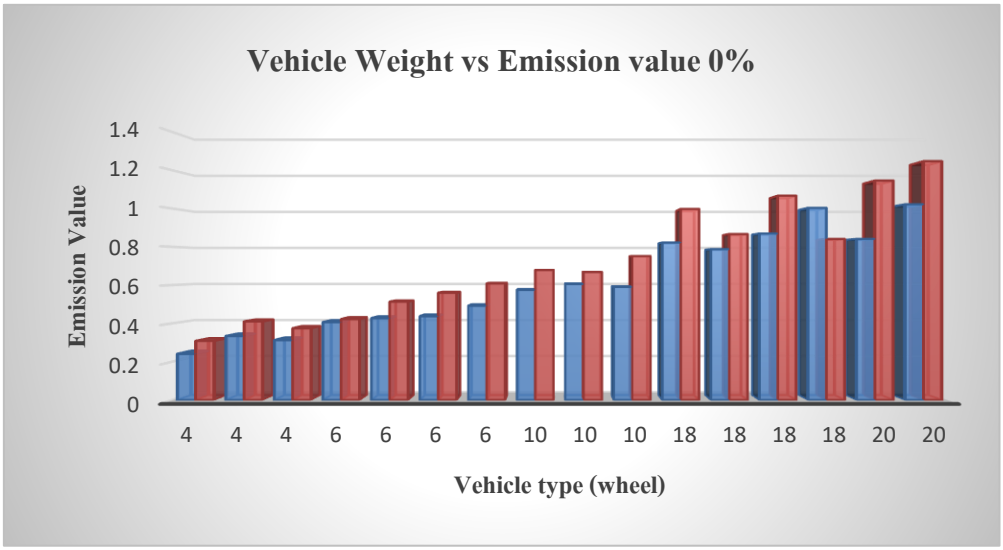


**Figure 5** Vehicle Type (Wheel) vs Emission value with 0% load

From graphs 6, 7 and 8, found that the weight of the load per trip 50,75,100 percent affects the emission value, as shown in the graph. The orange bar graph (4 wheeler) has the highest emission values. and the bar graph decreases as the weight increases.

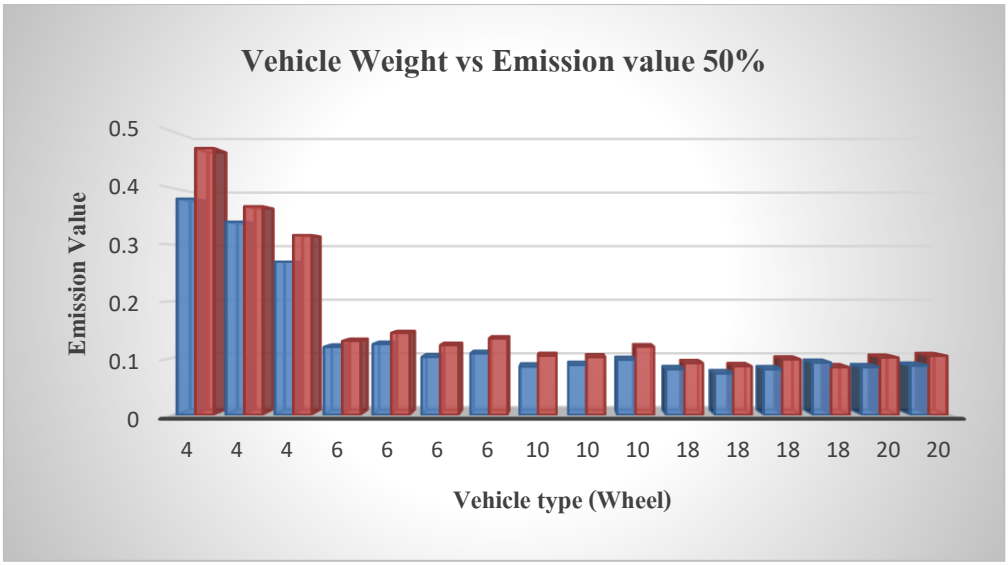


**Figure 6** Vehicle Type (Wheel) vs Emission value with 50% load

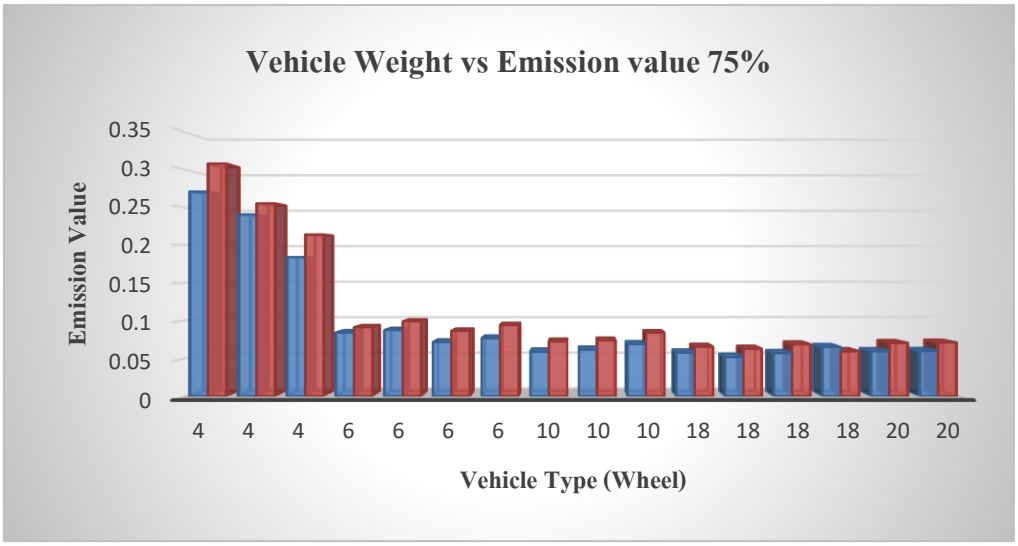


**Figure 7** Vehicle Type (Wheel) vs Emission value with 75% load

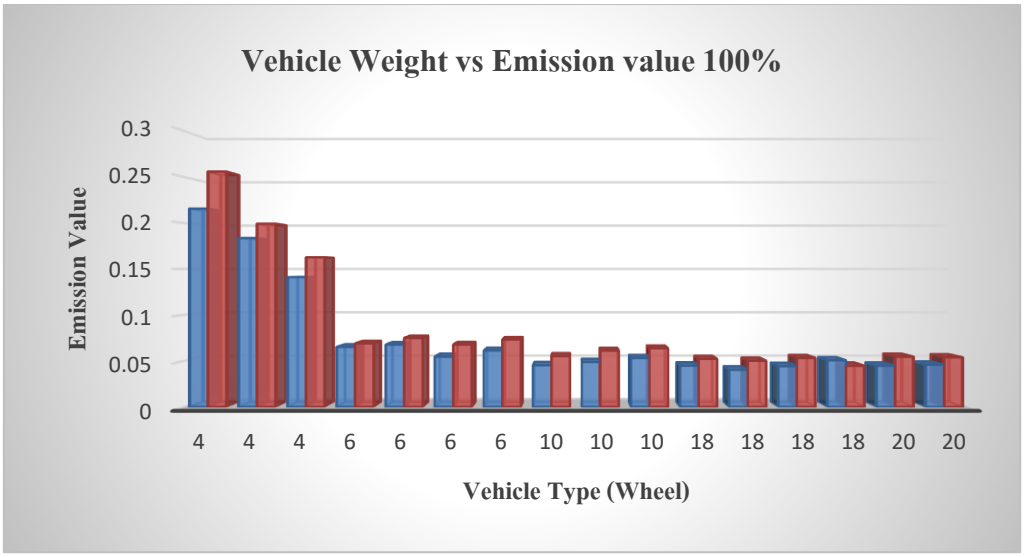


**Figure 8** Vehicle Type (Wheel) vs Emission value with 75% load

## 6. CONCLUSION

The data from the graph shown in fig. 9 compares the emission values from transport per trip with different loads, such as 0,50,75 and 100 percent, and 6 types of vehicles used for transport, for example: 4,6,10,18,20 wheels. From the graph, summarizing the importance of factors affecting the emission value, namely, the weight of the load per trip is the most influential factor.

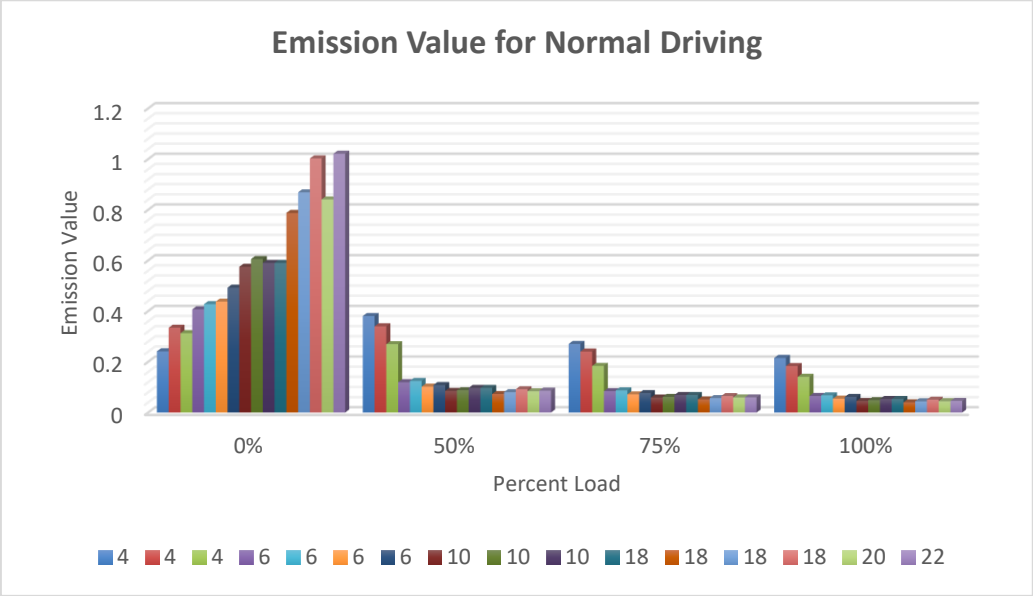


**Figure 9** Vehicle Type (Wheel) vs Emission value

A conclusion of the related factors of the variables by Tukey HSD found that the factors were significantly correlated, as shown in Table 4, only the relationship C, the driving method was not significant.

**Table 3** Descriptive statistic with ANOVA

***Descriptive statistics of your $k$=4 independent treatments:***

| Treatment → | A | B | C | D | Pooled Total |
|---|---|---|---|---|---|
| observations N | 128 | 128 | 128 | 128 | 512 |
| sum $\sum x_i$ | 2,351.0000 | 7,200.0000 | 192.0000 | 31.9505 | 9,774.9505 |
| mean $\bar{x}$ | 18.3672 | 56.2500 | 1.5000 | 0.2496 | 19.0917 |
| sum of squares $\sum x_i^2$ | 59,092.5000 | 580,000.0000 | 320.0000 | 18.2457 | 639,430.7457 |
| sample variance $s^2$ | 125.2854 | 1,377.9528 | 0.2520 | 0.0809 | 886.1259 |
| sample std. dev. $s$ | 11.1931 | 37.1208 | 0.5020 | 0.2844 | 29.7679 |
| std. dev. of mean $SE_{\bar{x}}$ | 0.9893 | 3.2810 | 0.0444 | 0.0251 | 1.3156 |

**Table 4** Tukey HSD results

**Tukey HSD results**

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 22.1063 | 0.0010053 | ** p<0.01 |
| A vs C | 9.8427 | 0.0010053 | ** p<0.01 |
| A vs D | 10.5724 | 0.0010053 | ** p<0.01 |
| B vs C | 31.9490 | 0.0010053 | ** p<0.01 |
| B vs D | 32.6786 | 0.0010053 | ** p<0.01 |
| C vs D | 0.7297 | 0.8999947 | insignificant |

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